8.2.3 ELECTROMAGNETIC SPECTRUM

Recent technological developments have allowed greater use of the electromagnetic spectrum

3.1 Describe electromagnetic waves in terms of their **speed in space** and their **lack of requirement of a medium for propagation**

- Is a **self-propagating** wave – changing **electric** and **magnetic** fields which oscillate perpendicular to each other
- Travel at the **speed of light – $3.0 \times 10^8 \mathbf{m/s}$** in a vacuum
    - Since velocity is the same for all EM waves, **frequency and wavelength** change ($v = f\lambda$)

Ray	Radio	Microwave	Infrared	Visible	UV	X-rays	Gamma rays
λ (m)	$> 10^{-1}$	10^{-1} to 10^{-4}	10^{-4} to 7×10^{-7}	7×10^{-7} to 4×10^{-7}	4×10^{-7} to 10^{-9}	10^{-9} to 10^{-12}	$> 10^{-10}$
Sources	TV/radio	Microwave ovens	Sun Warm objects (fire/people)	Sun Hot objects Lamps/Lasers	Sun Hot objects Sparks	X-ray tubes	Radioactive nuclei atoms Cosmic rays

3.2 Identify the electromagnetic **wavebands filtered out by the atmosphere**, especially **UV, X-rays and gamma rays**

Ray	Effect of Atmosphere
Radio	**Not absorbed,** >102 m λ reflected by ionosphere
Microwave	**Not absorbed**
Infrared	**Partially absorbed** by water vapour and carbon dioxide
Visible	**Not absorbed**

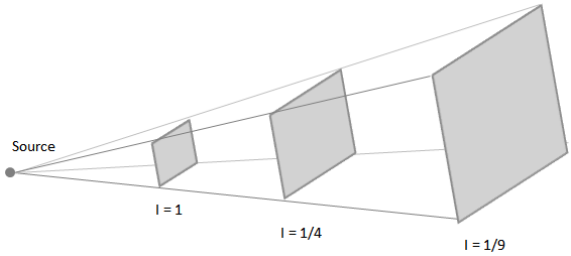
- Atmosphere has two main filters – **ionosphere** and **stratosphere**, humans live in troposphere
- **Ionosphere**, 50 to 500 km above Earth, composed of ionised gases – Regions D, E and F
    - D: 50-80 km, **gamma rays** and shorter λ **Hard X-rays** absorbed
    - E: 80-145 km, longer λ **Soft X-rays** absorbed
    - F: 145-300 km, short λ **UV** absorbed
- **Stratosphere**: longer λ **UV** absorbed

3.3 Identify **methods for the detection** of various wavebands in the electromagnetic spectrum

Ray	Method of Detection
Radio	Radio receivers connected to aerials
Microwave	Aerials, satellites
Infrared	Skin, night vision goggles
Visible	Eye, photographic film, photo cells
UV	Photographic film, photocells, fluorescent chemicals
X-rays	Photographic film, fluorescent screen
Gamma rays	Photographic film, Geiger counter

3.4 Explain that the relationship between the **intensity** of electromagnetic radiation and **distance** from a source is an example of the **inverse square law**: $\mathbf{I \propto \frac{1}{d^2}}$

- **Intensity** (measured in lux, lx) is reduced by the **inverse square** of the distance
- A light source with 16,000 lx:
  - 2 metres away would be $\frac{1}{2^2} \times 16000 = 4000$ lx
  - 3 metres away would be $\frac{1}{3^2} \times 16000 = 1777.8$ lx



3.5 Outline how the **modulation** of amplitude or frequency of visible **light**, **microwaves** and/or **radio waves** can be used to **transmit information**

RADIO WAVES

- Energy carried by waves can be **varied** to transmit information by varying **frequency or amplitude**
  - Frequency Modulation (**FM**) or Amplitude Modulation (**AM**)
  - Information is carried through signals by **superposition** of a **carrier** wave – **tuning frequency**
  - Signal occupies a range of frequencies around the carrier frequency – **bandwidth**
- Receiver subtracts carrier wave from signal and interprets variation in frequency/amplitude – **demodulation**
- **AM** advantage – uses much **narrower** range of frequencies – more stations fit into limited bandwidth
- **FM** advantage – **not dependent** on **amplitude changes**, so strength of signal does not change (frequency difficult to change due to interference)

MICROWAVES

- Greater **available bandwidth** (20,000 phone calls), **higher transmitted energy** (less spread out)
- Reception in **buildings** more difficult due to short λ, range affected by **atmospheric conditions** (oxygen)

LIGHT

- **High energy laser light** using **amplitude modulation** (frequency bandwidth too small for light)
- **Fibre optic cables** required – only reliable to 200 m in open air, due to more interference (narrow frequency)

3.6 Discuss **problems** produced by the **limited range** of electromagnetic spectrum available for **communication purposes**

- **Congestion** of frequencies – bandwidth allocations required
- Example: **FM** radio stations allocated with 0.2 MHz bandwidth – possible frequencies of 96.7, 96.9, 97.1, etc